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BREECH BLAST EMITTED FROM RECOILLESS RIFLES.(U)
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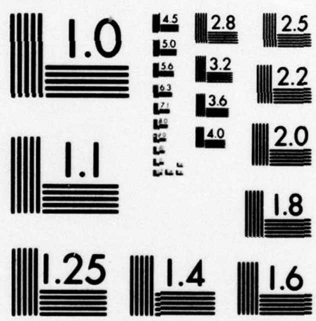
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this study was to develop simplified empirical equations and graphical solutions whereby estimates can be made of the breech blast pressure and impulse fields around the breech of any recoilless rifle. Two empirical equations were developed by conducting a model analysis, reviewing recoilless rifle firing test data, and supplementing the data base in the literature with test results of our own from a specially designed propellant chamber and variable area nozzle test device. The equations which result can be used with any size propelling charge in any caliber of recoilless rifle.

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August 6, 1979

FINAL REPORT
ON
BREECH BLAST EMITTED FROM RECOILLESS RIFLES

written by

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San Antonio, Texas

STATEMENT OF THE PROBLEM

The air blast wave emitted from the breech of a recoilless rifle during its firing is very intense. This air blast wave is a major concern of weapon designers, engineers mounting recoilless rifles on helicopters, airplanes, and vehicles, and those concerned with gun crew hearing loss and safety. No logically planned reduction in recoilless rifle breech blast pressure and impulse would be possible until the interactions of location relative to a gun's breech, the propellant chamber pressure, weapon size, expansion ratio of the nozzle, propellant chamber volume, quantity of propellant, and type of propellant were all understood.

Various investigators at Ballistic Research Laboratory and at the Naval Surface Weapons Center have been evaluating recoilless rifle breech blast using computational computer techniques. Aft of the breech, these analytical efforts have had success, but forward of the breech where pressure gradiants are very steep and where the corner must be turned computationally, the computer codes have had little success. Unfortunately, this region forward of the breech is where the gunner's head is located alongside a gun tube. In addition, design engineers often reject complex computer codes as being impractical and expensive for obtaining approximate answers.

Thus, the purpose of this study was to develop simplified empirical equations and graphical solutions whereby estimates can be made of the breech blast pressure and impulse fields around the breech of any recoilless rifle.

SUMMARY OF RESULTS

The following two empirical equations were developed by conducting a model analysis, reviewing recoilless rifle firing test data, and supplementing the data base in the literature with test results of our own from a specially designed propellant chamber and variable area nozzle test device. The equations which result can be used with any size propelling charge in any caliber of recoilless rifle.

$$\ln(\bar{P} \times 10^{+3}) = 7.579 - 0.034330 - 1.2134\ln \bar{L} + 0.005526\theta\ln\bar{L} \tag{1}$$

$$\bar{I} = \{14.41 - 14.26[\tanh^{1/2}(\frac{\theta}{30})] + 9.7[1 - \tanh(\frac{\theta}{5})]\}\bar{\ell}^{[-0.79 + 0.715\tanh(\frac{\theta}{25})]} \tag{2}$$

where

$$\bar{P} = \frac{P}{mP_c}(\frac{A_e}{A_t})^2$$

$$\bar{I} = \frac{I}{\sqrt{P_c}}(\frac{A_e}{A_t})^2$$

$$\bar{L} = \frac{NL}{\sqrt{A_e}}$$

$$\bar{\ell} = \frac{L}{\sqrt{A_e}}$$

and where

θ = the angle in degrees from the center line of the rifle (0° is directly aft)

A_e = effective nozzle exit area--can be less than the actual A_e if nozzle is poorly designed so the flow can not fully expand.

A_t = nozzle throat area

P_c = maximum propellant chamber pressure

P = side-on blast pressure

I = side-on specific impulse

L = distance from the breech

m = shape factor associated with chamber pressure time history. Approximately equals the average chamber pressure divided by the maximum chamber pressure.

N = shape factor associated with type of nozzle. Equals 1.0 for central oriface nozzle but equals $e^{0.001287\theta^{3/2}}$ for kidney nozzles.

Equations 1 and 2 are valid for θ from 0 to 150 degrees and for $\frac{L}{\sqrt{A_e}}$ directly aft of the breech from 15 to 300, perpendicular to the nozzle of from 10 to 220, and directly forward of from 2 to 20. Forward of the nozzle caution should be used because only the breech blast contribution is being evaluated without any interaction from nozzle blast waves.

Because the functional format interrelating the various parameters in equations 1 and 2 is fairly complex, it is easier to graphically present the results. Equations 1 and 2 in functional format are three-parameter spaces of nondimensional numbers. Either a nondimensional pressure $\frac{P}{mP_c}(\frac{A_e}{A_t})^2$ or a scaled impulse $\frac{I}{\sqrt{P_c}}(\frac{A_e}{A_t})^2$ is a function of the polar coordinate scaled positions in space [$\frac{L}{\sqrt{A_e}}$ or $\frac{NL}{\sqrt{A_e}}$ and θ] where the quantities are to be predicted. Figures 1 and 2 are three-parameter plots, in rectangular rather than polar coordinates, with contours of either scaled constant blast pressure or scaled specific impulse. The solid contour lines cover regions where pressures and impulses were measured and dashed contours cover regions where pressure and impulse has been extrapolated. Inserts have been added in the upper right hand corners of figures 1 and 2 to expand the graphical solution in the region, forward of the breech, where the gunner's head is located.

The pressure contours, seen in figure 1, have the elliptical shape which is typical of recoilless rifle firings. On the other hand, the impulse contours, seen in figure 2, exhibit long fingers radiating away from the source. Over the entire mapped region, scaled impulse is much closer to being constant than is scaled pressure. Along any radial line at a constant angle from the breech of a recoilless rifle, scaled impulse changes very little.

COMPARISON WITH TEST DATA

Experimental pressure data were taken from the literature for such guns as 57 mm T66E6, 57 mm M18A1, 75 mm T21, 90 mm T219, 105 mm modified M27, 105 mm T19, and 106 mm T170E1. This data base was supplemented with SwRI measured breech blast pressures obtained using a special chamber on

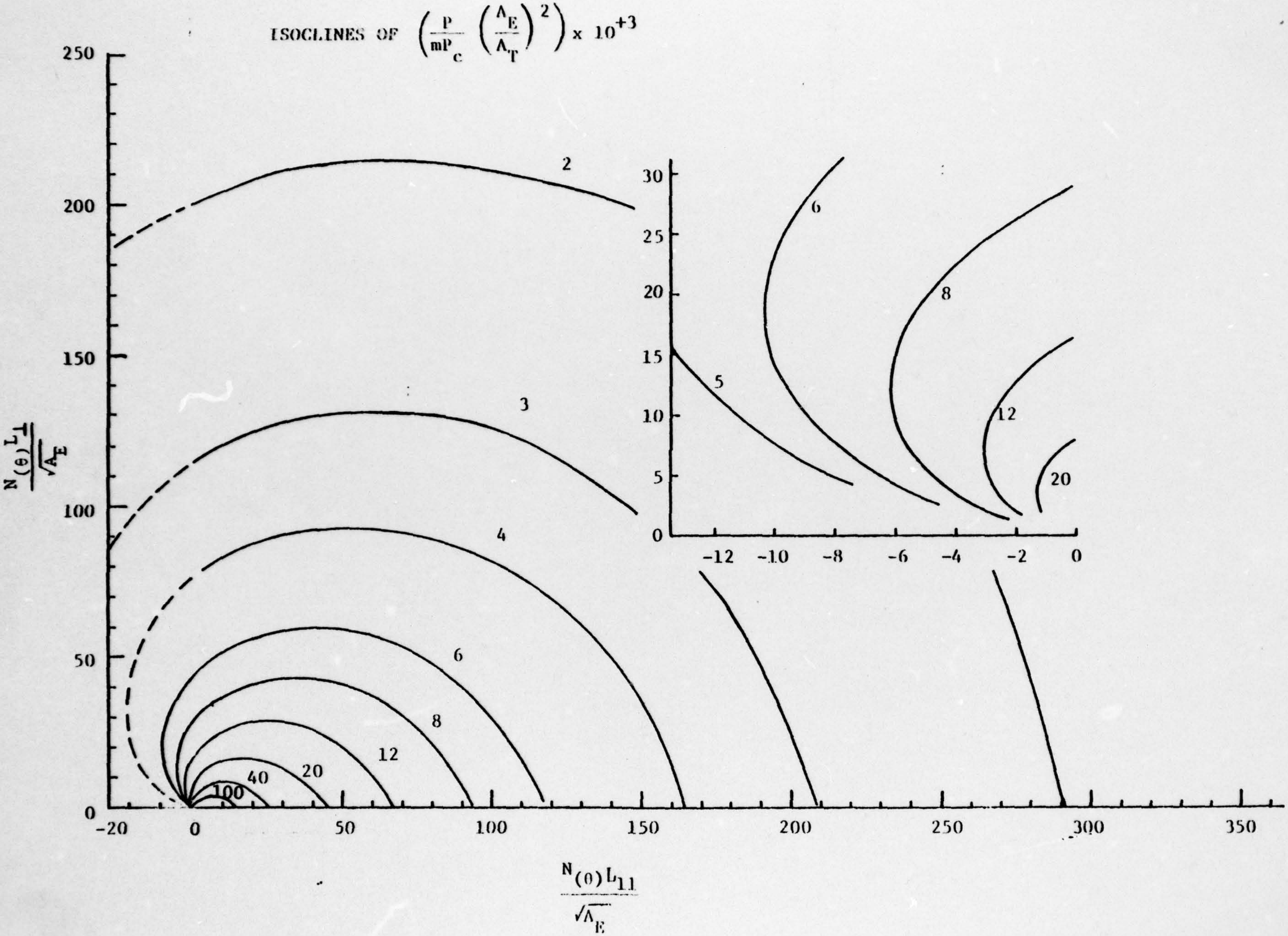

FIGURE 1. FREE FIELD BLAST PRESSURES AROUND THE BREECH OF RECOILLESS RIFLES

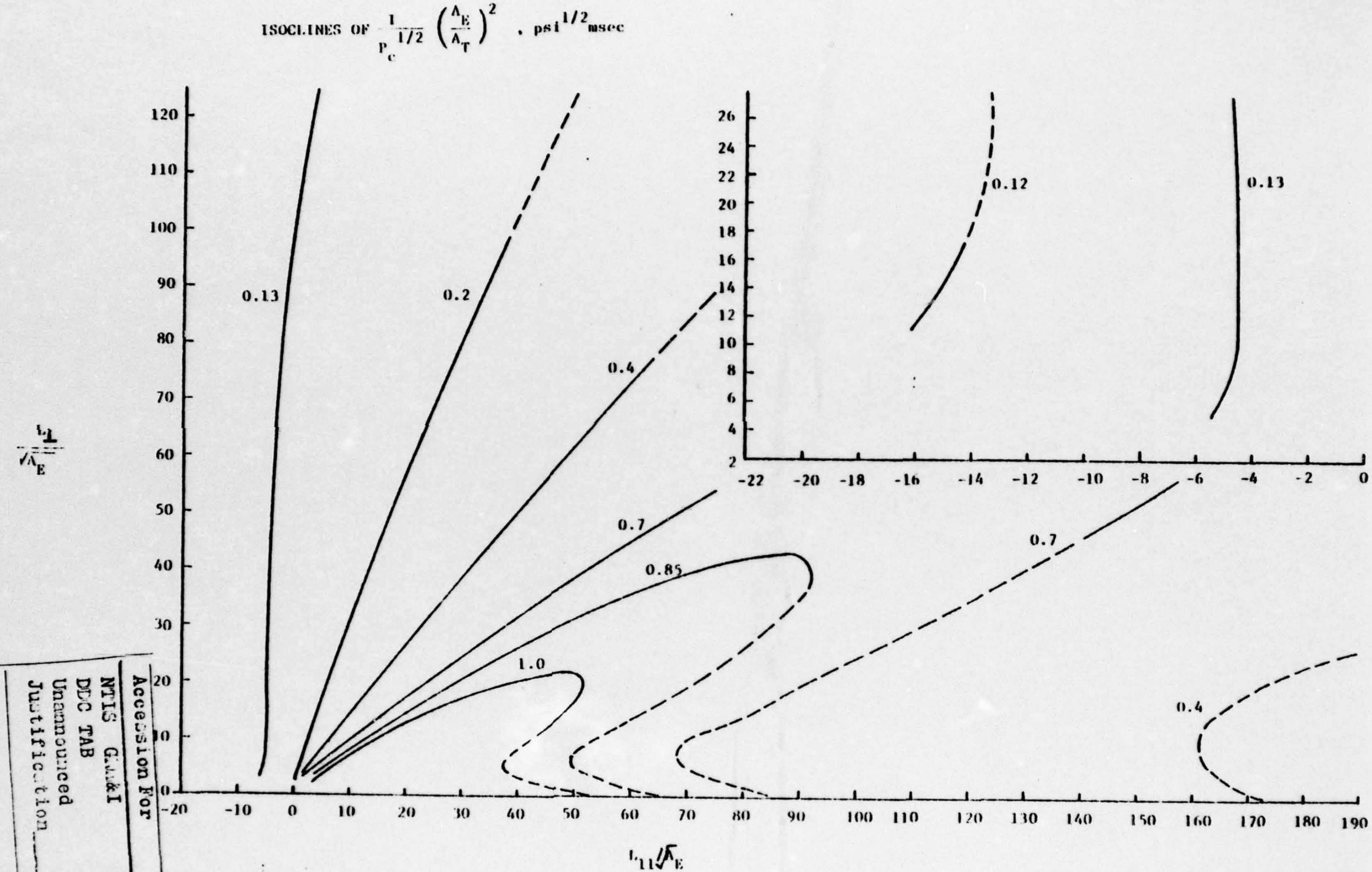

FIGURE 2. FREE FIELD IMPULSE AROUND THE BREECH OF RECOILLESS RIFLES

which nozzles, chamber volume, quantities of propellant, and type of propellant could all be changed independently or in combination. Then plots of scaled pressure were made versus scaled standoff distance for constant values of the angle θ. Eleven different scaled pressure plots were made for constant values of θ in 15 degree increments from 0 to 150 degrees. Two of these plots are shown as Figures 3 and 4. The solid line through the data points is the curve fit given by equation 1.

Similarly scaled impulse plots were made for constant values of θ in 15 degree increments from 0 to 150 degrees as seen in Figures 5 and 6. Not as much recoilless rifle impulse data are available in the literature as pressure data because investigators have just begun to realize the importance of impulse and reducing records to obtain impulse requires addition work. Thus, with the exception of a 57 mm gun and two 105 mm weapon systems, the majority of the impulse data are from our test firings with the special propellant chamber. Once again the solid line is the curve fit, except for impulse, the curve fit is given by equation 2.

SOURCE FOR ADDITIONAL DETAILS

Although only two pressure and two impulse plots are shown in this summary, comparisons along all the other radial lines can be obtained from a paper which has been submitted to the 1979 Shock and Vibration Symposium. This paper was preceeded by another one giving the history of efforts to scale gun blast and the technical theory behind this approach. These papers are:

1. Peter S. Westine, Gerald Friesenhahn, and John Reigel, "Generalized Graphical Solution for Estimation Recoilless Rifle Breech Blast Overpressures and Impulses," 50th Shock and Vibration Symposium, Colorado Springs, Colo., October 1979 (Submitted for publication)
2. Peter S. Westine and Randall E. Ricker, "Empirical Procedures for Estimating Recoilless Rifle Breech Blast Overpressures," 49th Shock and Vibrations Symposium, Huntsville, Ala., October 1978

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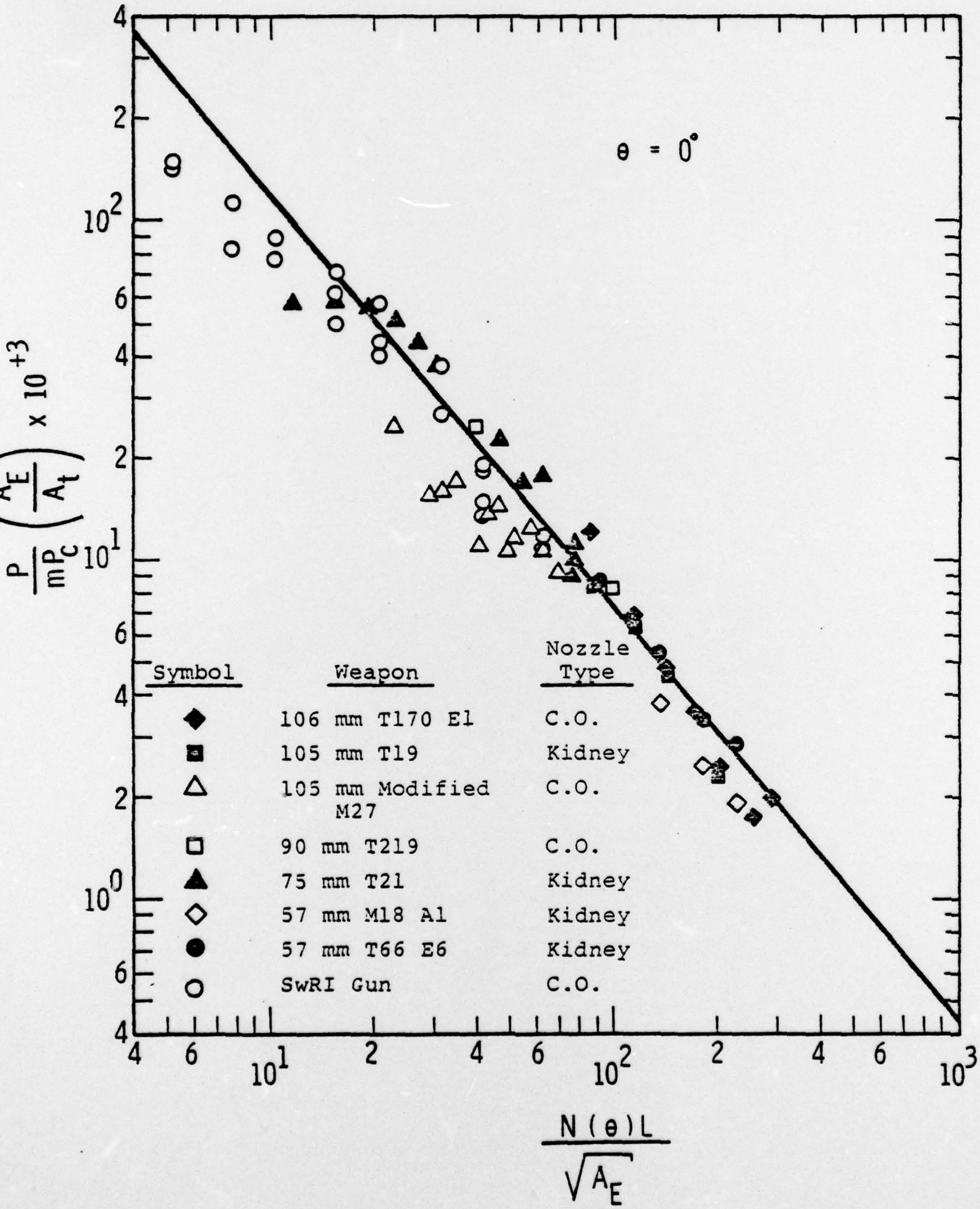

FIGURE 3. SCALED PRESSURE VERSUS SCALED STANDOFF DISTANCE FOR θ EQUAL 0°

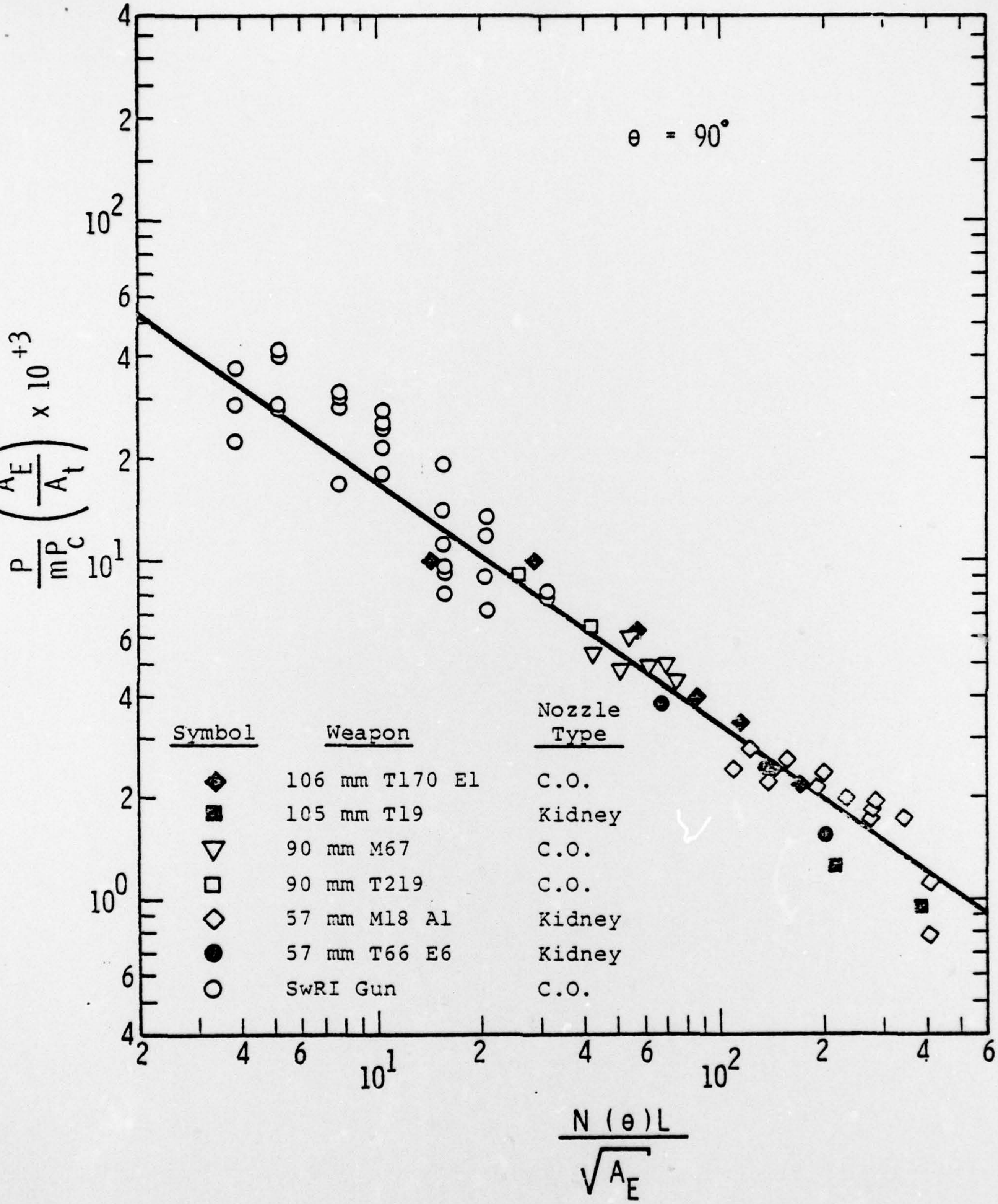

FIGURE 4. SCALED PRESSURE VERSUS SCALED STANDOFF DISTANCE FOR θ EQUAL 90°

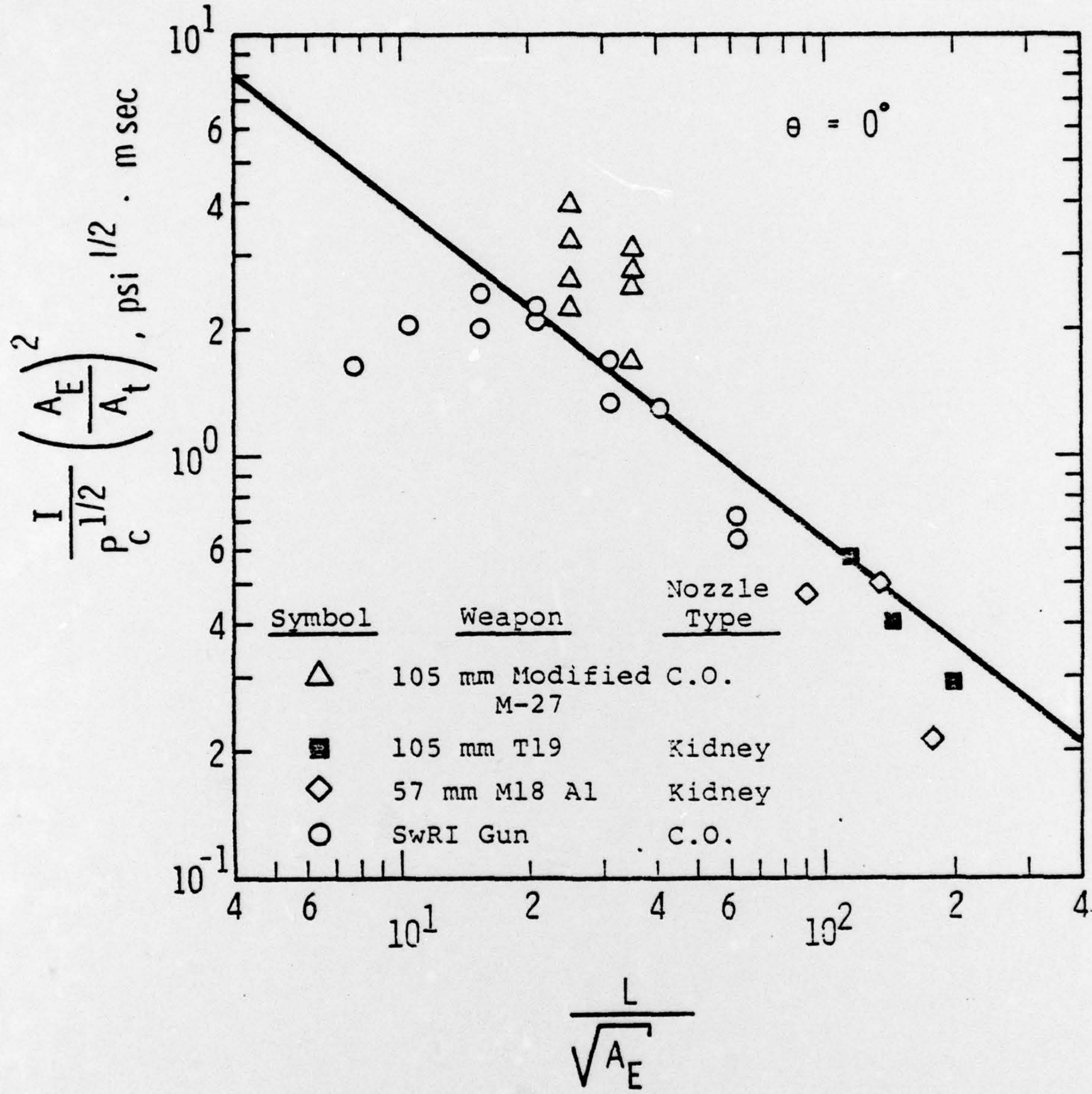

FIGURE 5. SCALED IMPULSE VERSUS SCALED STANDOFF DISTANCE FOR θ EQUAL 0°

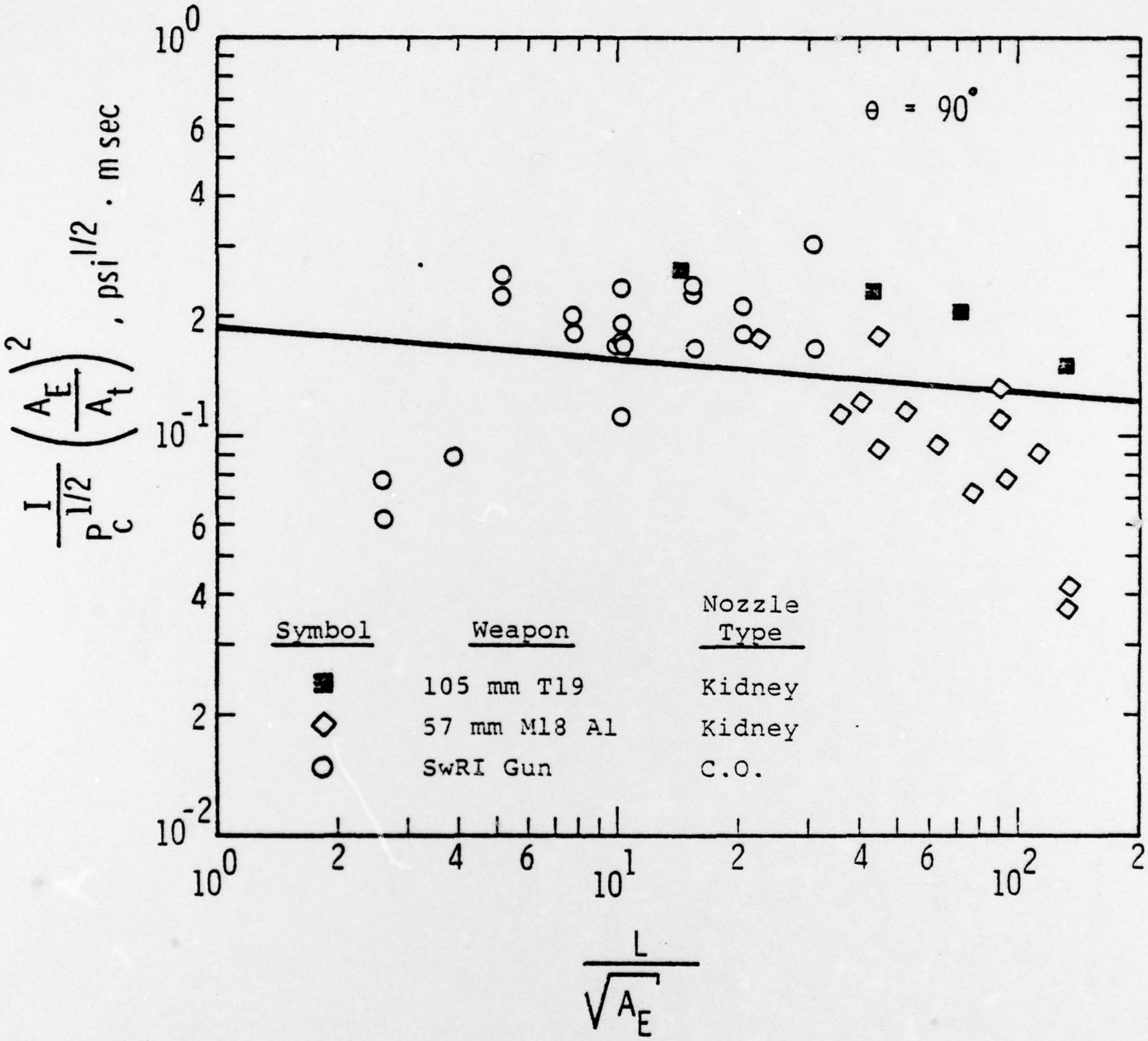

FIGURE 6. SCALED IMPULSE VERSUS SCALED STANDOFF DISTANCE FOR θ EQUAL 90°

Various Southwest Research Institute personnel assisted in this study. Mr. Randall Ricker, Mr. Gerard Friesenhahn, and Mr. John Reigel supervised the test program and assisted in curve-fitting the test results. Mr. Patrick Zabel designed and hud fabricated the propellant test chamber which was used to obtain large amounts of data. Mr. Marvin Burgamy, Mr. Richard Hoffman, Mr. Ernest Garcia, and Mr. Richard Cervantes conducted all SwRI experimental gun firing tests. Mr. Victor Hernandez drew all figures in this report, and either Mrs. Cooke or Mrs. Carroll typed this and all reports. The assistance of these individuals and that of those who are always inadvertently overlooked is greatly appreciated.